No 3301

FISH & WILDLIFE SERVICE
PACIFIC OCEANIC FISHERY
INVESTIGATIONS

APR 25 1952

PROCEEDINGS OF THE UNITED STATES NATIONAL MUSEUM

issued *by the*

SMITHSONIAN INSTITUTION
U. S. NATIONAL MUSEUM

Vol. 102 Washington: 1952 No. 3301

AN EMENDED DIAGNOSIS OF THE COPEPOD GENUS PUPULINA (CALIGOIDA), WITH DESCRIPTIONS OF NEW SPECIES AND A REDESCRIPTION OF THE GENOTYPE

By Mildred Stratton Wilson

The caligoid copepod parasite *Pupulina* has been an imperfectly known genus since its discovery in 1892. The original description by van Beneden was incomplete, and attached to it, as the description of the male, was the diagnosis of an immature female of another genus. Not until 1935 was its validity definitely established, by Dr. Charles Branch Wilson, through the description of both sexes of the genotype, *Pupulina flores*. One subsequent record of the species has been made, that of Bere (1936).

This seeming rarity and the incompleteness of knowledge that always results when but a single member of a genus is known add interest to the recent discovery of two new species. These occurred together on a specimen of the giant ray *Mobula lucasana* Beebe and TeeVan, taken off the coast of California. The copepods were removed from its surface by Prof. G. E. MacGinitie, who referred them to the United States National Museum for identification. The host, the second of its kind to be drawn to the attention of science, was also of particular interest, and salient facts concerning it have already been noted in a publication by MacGinitie (1947).

The collections of both Wilson and Bere are in the United States National Museum and thus, fortunately, available for study. A direct comparison of the new species with *Pupulina flores* has made possible a new, nearly more complete diagnosis of the genus; especially has it indicated the importance of certain characters hitherto not stressed or noted. In addition, it has been found that some of the

specimens identified by Bere as *Pupulina flores* are referable to the smaller of the two new species.

A new description, based on the Wilson and Bere specimens, has been prepared for the genotype, as much detail having specific value has been previously omitted. Development forms, present in his material and not mentioned by Wilson, are also described.

For critical readings of the manuscript I am indebted to Dr. Charles H. Martin, of Oregon State College, and to Paul L. Illg, of the United States National Museum.

HOST RECORDS

According to each of the three published instances of the occurrence of *Pupulina*, it has been found on a species of large ray belonging to the family Mobulidae. From this fact and MacGinitie's discovery it would appear that the genus may be a specific parasite of this group of rays. It seems very probable that records of its occurrence have been infrequent because the hosts themselves are seldom caught.

In this connection, it is necessary to qualify Wilson's statement (1935a, p. 593) that his specimens, taken near the Galápagos Islands, were from "*Manta birostris*, the same species of fish as that from which Beneden's specimens were collected." Van Beneden did not so name the species of the host, merely alluding to it as *Ceraptopterus*. The latter is a genus of Coleoptera, and so far as is known to me, the name has not been used in the fishes. From van Beneden's description of the size of the host, it is probably safe to assume that he had confused the name with *Ceratoptera* Müller and Henle, a synonym of *Manta*. Van Beneden's specimens occurred off the Azores, a locality considerably removed from the Galápagos, and whether the host was the identical species of *Manta* is certainly open to question.

Genus PUPULINA P. J. van Beneden

Pupulina VAN BENEDEN, 1892, p. 254.—C. B. WILSON, 1935a, p. 593.

Diagnosis (emended).—Body form of more or less specific variability in females; strikingly similar in males.

Frontal plates well defined, without lunules. First three thoracic segments fused with head; fourth segment free, without dorsal plates. Lateral, cephalic, and thoracic areas of carapace demarcated dorsally by well-defined grooves; ventral supporting ribs of lateral areas stout, the posterior of double rods, their outlines usually conspicuous dorsally.

Genital segment of female moderately enlarged, its width greater than that of free segment, about one-half to three-fifths that of carapace; the posterior corners produced into backwardly directed

lobes; dorsal surface with a large medial clear area in which the integument is considerably thinner than that surrounding it, creating in the mature forms a characteristic design for each species. Abdomen narrow and elongate in both sexes, 3-segmented in the female, the division between the first two segments sometimes indistinct; 2-segmented in the male. Caudal rami linear in male; either linear or short and broad in female; terminal setae very short, sparsely plumose or naked.

Second antenna of female with either two or three segments well defined, apical claw stout, basal segment with a strong, posteriorly directed spinous process; that of male 3-segmented, tipped with a stout claw and armed variously with laminae and spines. Prehensile lateral hooks present, the basal portion bearing posteriorly two papillae armed with branched or simple setae.

Oral appendages similar to those of the Caliginae. Mouth tube in female constricted near the middle, its greatest width a little more than half the length of the entire tube; the whole more slender and hardly constricted in the male; opening subterminal. Mandible 4-segmented, segments 2 and 3 imperfectly defined, claw heavily chitinized, with teeth on the inside margin only.

First maxilla consisting of two heavily chitinized pieces and a very small, membranous papilla, the outer chitin piece having its outside edge more or less produced distally, being extended in the genotype into an elongated process; the inner piece (usually referred to as endopod by recent writers) extended posteriorly into a slender spinelike process, in the male either branched distally or bearing an articulated spine. The papilla (the exopod of recent writers) arising from the ventral face between the basal portions of the two chitin structures; bearing three comparatively short setae which exhibit sexual as well as pronounced specific differences. Second maxilla elongated; first segment imperfectly defined, represented by a slightly enlarged basal portion; third segment very slender, with two thin, curving, terminal claws, the posterior of which is much shorter than the other. Maxilliped of female with short terminal claw, not more than half the length of basal segment; male having claw a little longer and the basal segment variously armed.

Two pairs of accessory processes arising from the ventral face, sexually similar. The anterior pair spinelike, situated near distal end of the inner chitin piece of the first maxilla. The posterior pair heavily chitinized or membranous, shape specifically variable, located behind the base of the maxilliped, directly opposite the posterior supporting lateral ribs of the carapace, but in nowise connected with them or with the central area usually occupied by the furca, which is lacking.

Legs 1–3 biramose. Leg 1 with both rami 2-segmented, the endopod well developed; the inside spine of the second exopod segment charac-

teristically branched in each species. Curved chitin rods, sometimes armed with spines or spinous processes, between bases of legs 1 and 2. Leg 2 with trimerous rami; outer spines of exopod 1 and 2 only moderately developed; endopod 1 and 2 with outer marginal laminae.

Leg 3 having both rami 3-segmented, their bases set closely together. Exopod well developed, the first segment elongate as in the second leg, outer spines weaker. Endopod 1 and 2 with outer laminae, that of segment 1 greatly enlarged and overlying the exopod, that of segment 2 much smaller; the second segment the longest, with two inner setae arranged like those of the second leg; third segment approximately the same size as the first segment, with four terminal setae.

Leg 4 uniramose and stout; 4-segmented, the basal segment greatly broadened; somewhat sexually dimorphic in armature; some species having short spines on the inner margins of segments 2–4; the sutures between these segments transverse. No rudiments of legs 5 and 6 visible on genital segment of adult, but present on the ventral side in female chalimi; condition in immature male not observed.

Length of known females, 6–15 mm.; of males, 4.8–12 mm.

Parasites of giant rays.

Genotype.—*Pupulina flores* P. J. van Beneden.

PUPULINA FLORES van Beneden, new description

PLATE 12; PLATE 14, FIGURES 8–11

Pupulina flores VAN BENEDEN, 1892, p. 254, pl. 3, figs. 6–8, female.
Lepeophtheirus flores, BASSETT-SMITH, 1899, p. 455.
Lepeophtheirus flores, C. B. WILSON, 1905, pp. 617, 618, in key.
Pupulina flores, C. B. WILSON, 1935a, p. 594, figs. 1–13, female and male.
Pupulina flores, C. B. WILSON, 1935b, p. 331, refers van Beneden's male to *Paralebion elongatus* female.
Pupulina flores, BERE, 1936, p. 590, the "large female."

Specimens examined.—Six mature, two immature females; two mature males, U.S.N.M. No. 60439. Host: *Manta birostris* (Walbaum). Locality: near the Galápagos Islands. Identified by Charles Branch Wilson.

One female, U.S.N.M. No. 79150. Host: "probably *Mobula hypostoma* (Bancroft)." Locality: Lemon Bay, Fla., Gulf of Mexico. Identified by Ruby Bere.

Diagnosis.—Anterior (cephalothorax) and posterior parts of body approximately equal in length in both sexes. Processes of female genital segment reaching a little beyond the middle of the abdomen. Caudal rami attached terminally, linear; those of female only a little shorter than the abdomen; those of male longer. Outer chitin piece of first maxilla extended distally almost to tip of the process of the inner piece; the latter bifurcate in male. Maxilliped of male with a short papillalike process on the basal segment. Posterior ventral

accessory processes large, heavily chitinized, triangular spines. Leg 4 without inside spines on segments 2–4, but with a cuticular process on 4.

Description.—Female (pl. 12, fig. 1): Galápagos specimens: Total length 13.9–15.0 mm. Carapace about 6 mm. long, 5.8–6.0 mm. wide. Gulf of Mexico specimen: The single, nonovigerous female only 10 mm. in length, but otherwise like the Galápagos specimens.

Anterior margin of carapace curved, median sinus slitlike; posterior margin nearly straight. Grooving of carapace as in pl. 12, fig. 1; lateral lobes with long slender hairs dorsally; each side of distal edge of thoracic area set with four or five spines. Free segment about three times wider than long, with short dorsal spines posteriorly.

Genital segment joined by short neck to the free segment, rounded anteriorly; posterior processes reaching slightly beyond midpoint of second segment of abdomen, ending in slender, rounded tips, diverging inside directly from the base of the abdomen. Sides of segment and parts of dorsal surface set with very short spinules. Design on dorsal surface sloping in a wavy line from the rather straight top to the widened central area; the posterior part narrowed with a marked central incision of the entire bottom margin.

Abdomen narrow and elongate, a little longer than the genital segment in midline; the first segment very short and indistinctly defined; the second and anal segments plainly demarcated from each other, the second twice the length of the anal; both distal segments with a midline of long, coarse hairs and scattered surface spinules; anal segment with a pair of dorsal longitudinal ridges distally.

Caudal rami a little shorter than the abdomen, flattened laterally, proximally with a raised longitudinal ridge; dorsal margins set with coarse hairs; terminal setae very short and nonplumose, three in number. Ovisacs slender, longer than the caudal rami.

The first antenna (pl. 14, fig. 9) with a double row of stout plumose setae on the upper side of the first segment and two short spines distad on the lower side; the narrowed terminal segment having a slender seta midway on the lower margin, and the apex set with numerous short spines and varied setae (pl. 14, fig. 8).

Second antenna (pl. 12, fig. 4) 2-segmented, basal spinous process very slender, terminal claw curved inwardly, only moderately elongated. Lateral prehensile hooks (pl. 14, fig. 5) comparatively long and strongly curved, setae of basal papillae branched. Mouth tube as described for the genus; mandible with 12 teeth.

The anterior accessory process of the ventral face (pl. 14, fig. 7) located near the distal inner side of the inner piece of the first maxilla; consisting of a very stout spine about one-fourth as long as this portion of the maxilla. The outer piece of the first maxilla (pl. 12, fig. 8) well developed, its outer edge elongated and spinelike distally, reaching

beyond the middle of the inner piece; the papilla seemingly closely associated with the tissue of its inner basal portion. The three papillary setae unequal and unlike (pl. 12, fig. 15), the shortest having an accessory spine near its midline. The inner piece of the maxilla longer than the extension of the outer piece, ending in a similar stout, slightly curved spine.

The second maxilla (pl. 12, fig. 9) of the long slender form characteristic of the genus, tipped with two slender, unequal claws with marginal hyaline flanges, the posterior about half the length of the other. The claw of the maxilliped (pl. 12, fig. 10) slender, about half the length of the basal segment, bearing a stalked seta on its posterior side. The accessory process just posterior to the base of the maxilliped (pl. 12, fig. 11) a very broad, stout, chitinous spine, irregularly triangular, with the distal point somewhat attenuated. (The basal part of this spine is probably a bar corresponding to that found in the other species, but the main body is so strongly chitinized that any division between the two is obscured.)

Chitin rod between legs 1 and 2 narrow, curved backward, each side armed with a stout upwardly directed spine. Form of leg 1 as shown in plate 15, figure 14; endopod reaching to distal third of basal exopod segment; terminal exopod segment with the upper two spines stout and dentate on both margins, the modified inner spine and accompanying seta as shown in plate 12, figure 16.

Basal segment of leg 2 armed inside with a plumose seta and a triangular lamina. Exopod (pl. 12, fig. 18) with outer spine of first segment reaching to distal end of third; spine of third segment with smooth margins, reaching considerably beyond distal edge of segment; second spine about one-third the length of the first, smooth and slightly curved. Laminae on outer margins of endopod segments 1 and 2 similar to those shown in plate 15, figure 12, except that the edges are more rounded. (There is no lamina on the inner edge of the second segment as stated by C. B. Wilson, 1935a. As is usual, the margin of the segment is extended beyond the point of attachment of the succeeding segment, and bears two long setae at the distal terminus of the extension.) The third segment rounded and very short, bearing six setae.

The exopod of leg 3 having the basal segment as long as the two succeeding segments, the outer spines of segments 1 and 2 smooth, slender, and scarcely longer than the following segment. The inner setae not so long as those of leg 2. Segment 3 (pl. 12, fig. 14) with three outer unequal spines. The laminae of the outer margins of the endopod attached as shown in plate 12, figure 17; that of segment 1 very large and overlying the first two segments of the exopod. The inner margin of segment 2 expanded as in leg 2.

As my findings disagree with some of those of C. B. Wilson (1935a), the following summary of the armature of legs 1–3 is given (sp=spine; se=seta; lam=lamina):

	Exopod		*Endopod*	
Leg 1	sp		0	
	3sp	4se	3se	
Leg 2	sp	se	lam	se
	sp	se	lam	2se
	2sp	6se	6se	
Leg 3	sp	se	lam	0
	sp	se	lam	2se
	3sp	4se	4se	

Basal segment of leg 4 (pl. 12, fig. 20) with small spines on anterior and posterior margins; second segment with similar spines along outer margin; none on margins of segments 3 and 4. Terminal outer spines of segments 2 and 3 about as long as the succeeding segment, inner spines lacking. Distal end of fourth segment with three stout spines and one slender spine, the outermost shorter than the segment, the next as long as, and the third a little longer than the segment; the inner spine attached laterally, slender, curved, reaching beyond the end of the segment by one-half its own length; a thin, cuticular process, spinelike distally, present at about the middle of the inner margin. All large major spines of the leg coarsely toothed, the longest of the terminal segment having some of the teeth considerably enlarged on the inner margin, with three stout additional teeth on the outer side.

Male (pl. 12, fig. 3): Total length 11.4–12.1 mm. Carapace about equal in length and greatest width, 5.1–5.4 mm.; cephalothorax about 5.8–6.0 mm. long. Posterior part of body averaging 5.8 mm. in length; of this the approximate divisions are: genital segment, 1.3 mm.; abdomen, 1.9 mm.; caudal rami (exclusive of setae), 2.6 mm. The caudal rami are therefore longer than the abdomen, but are shorter than the genital segment and abdomen combined. None of the specimens, including the allotype (kindly measured for me by Paul Illg, of the United States National Museum), exhibit the condition described and figured by C. B. Wilson (1935a, p. 597) in which "the caudal rami are as long as the entire body behind the carapace."

Carapace similar to that of female except that the medial posterior edge is somewhat curved. Free thoracic segment little more than twice as wide as long; posterior part considerably widened at midline, with long, stiff marginal hairs.

Genital segment with sides slightly rounded, set with conspicuous spinules, both marginally and on dorsal and ventral surfaces; four-fifths as wide as long; posterior corners produced dorsally, well rounded ventrally. Basal segment of abdomen distinctly set off;

anal segment not demarcated by discernible transverse grooving either dorsally or ventrally in specimens examined, but with a pair of raised longitudinal dorsal ridges as in female, particularly noticeable in stained specimens. Both ventral and dorsal surfaces covered with scattered spinules. Caudal rami slightly less than one-third longer than the abdomen, flattened laterally as in female, with proximal dorsal ridges, inside margins with long hairs, outside with spinules.

Second antenna (pl. 14, fig. 10) reduced in size but very stout; basal segment unarmed, strongly united to ventral face of carapace (this segment is apparently omitted in C. B. Wilson's illustration, 1935a); second segment stout and well rounded, projecting upward, armed below with a broad but rather short spine, and a comparatively large, 2-layered, fringed lamina placed distad to the spine. Third segment with a stalked spine, segmented near its tip, and a stalked seta at the base of the claw. Claw short, but very strongly curved, with a rounded projection at its inner base. (The illustration of this appendage, pl. 14, fig. 10, is a flattened, semidiagrammatic view, turned so as to include detail of all the armature.)

Lateral prehensile hooks scarcely larger than those of female, but much more strongly curved, papillary setae unbranched. Anterior accessory process like that of female, but comparatively smaller. Inner piece of first maxilla (pl. 12, fig. 12) bifurcate at tip, inner branch the longer; basal portion of the outer piece broad, extended distally into a long spine as in female; setae of papilla unequal (pl. 12, fig. 15). Maxilla 2 as in female. Maxilliped (pl. 14, fig. 11) about twice the length of the second antenna, with a stout claw bearing a stalked seta; basal segment with a short, rounded process whose tip is more or less demarcated by a roughened area. Posterior accessory process behind maxilliped a stout triangular spine like that of female. Chitin rod between legs 1 and 2 also resembling that of female.

Legs 1–3 with setal formula and laminae like female. Basal segment of leg 4 (pl. 12, fig. 19) armed marginally with spinules; more spinules scattered over the upper part of the dorsal surface, and the lower part with a patch of long, stiff hairs running crosswise. The large spines of segments 2–4 more slender and comparatively longer than those of female; all having toothed margins, that of the longest terminal spine with the proximal teeth enlarged on the inner margin. Length of the shorter inner spine not known, as it is unfortunately broken off in all the specimens, including the allotype.

Development Stages: Two female chalimi, not mentioned by C. B. Wilson in his report, are present in the Galápagos collection. In the following descriptions, they are referred to as Stages *a* and *b*.

Stage *a* (pl. 12, fig. 2): Total length, 4.2 mm. All the first three thoracic segments incorporated in the carapace, which is as wide as long. Frontal plates indistinct. Free thoracic segment only slightly

wider than long, with small distal lobes; fourth legs attached near the middle of the segment. Genital segment separate from abdomen, widened anteriorly, narrowed posteriorly, with cuticular lobes on the sides at the midpoint; behind these, another pair of lobes that represent the beginnings of the posterior processes. Ventrally, these latter lobes carry the rudiments of leg 5, consisting of a small, rounded flap hardly differentiated from the surface and bearing terminally two short plumose setae; leg 6 not discernible in this specimen. Abdomen and caudal rami together only a little longer than the genital segment. Abdomen showing no segmentation. Caudal rami flattened dorsoventrally, with the plumose terminal setae longer than in the adult.

Ventrally, the fore part of the body showing the distinguishing characters of the species already developed. The outer piece of the first maxilla well extended distally; both anterior and posterior ventral accessory processes large and of distinctive shape, the posterior process more membranous than in the adult, with the distal attenuated point sharper. A pair of spinous processes between legs 1 and 2, the connecting rod between them scarcely discernible.

The second antenna segmented like that of the adult, but more slender, the terminal claw very strongly bent as in adult; prehensile lateral hook comparatively shorter. The second maxilla not at all strongly developed, the basal segment being shortened and not extending outward beyond the maxilliped as in the adult; the terminal claws (pl. 12, fig. 2, *a*) not demarcated basally from the apex, the posterior claw very short, broad and dentate.

Leg 1 with both rami 2-segmented and all setae present, the branching of the modified spine of the exopod incomplete. Rami of legs 2 and 3 only 2-segmented, the laminae not developed. Leg 4 relatively small, consisting of the basal and two other smaller segments.

Stage *b* (pl. 12, fig. 13): Total length about 9.3 mm. Metasome a little longer than urosome. Carapace slightly longer than wide. Fourth legs attached near the distal end of free segment, the widened area behind having disappeared; distal edges of segment somewhat angular.

Genital segment with processes reaching to about the proximal third of abdomen; rudiments of leg 5 on the ventral side having three setae, one lateral, two terminal, all shorter than the two setae of the preceding stage. Rudiments of leg 6, consisting of a very much abbreviated lobe and a single seta, located outside and slightly anterior to leg 5.

Abdomen 2-segmented dorsally, the short basal segment of the adult indistinctly demarcated ventrally; the anal segment distally with a pair of dorsal longitudinal lines, undoubtedly the beginnings of

the prominent ridges of the adult. Caudal rami a little shorter than the abdomen, terminal setae shorter than in Stage *a*.

All appendages considerably larger and more chitinized than in Stage *a*. Outer piece of maxilla 1 a more slender spine than in adult; claws of second maxilla longer, but of same general shape as in Stage *a*. Rod between legs 1 and 2 well developed. All legs with rami completely segmented; leg 4, however, not large, and its spines weak and flattened.

This chalimus is almost as long as Bere's specimen from the Gulf of Mexico which, however, is as completely developed as the adult.

Hosts and distribution.—*Manta* sp., Atlantic Ocean, near the Azores (van Beneden); *Manta birostris* (Walbaum), Pacific Ocean, near the Galápagos Islands (C. B. Wilson); "probably" *Mobula hypostoma* (Bancroft), Gulf of Mexico, in Lemon Bay, Fla. (Bere).

Remarks.—The identification of these Pacific and Gulf of Mexico specimens with the female of the type species from the Atlantic would seem from a comparison with van Beneden's original description and illustrations to be correct. His drawing of the female shows the same general shape of the various parts of the body, and the dorsal design on the genital segment is closely similar, the midinvagination of the posterior margin being characteristic of the species. His illustration differs in that the anterior lobe of this design is considerably narrower and the sides longer. In his figure, also, the posterior inside margins of the genital segment are more rounded with the corners less produced, and the abdomen is unsegmented and longer in proportion to the genital segment.

The only illustrations van Beneden gave of the appendages are some very incomplete figures of those of the cephalic area. These, however, show two important characteristics of the species: The extension of the outer portion of the first maxilla into a slender spine, and the triangular shape of the posterior ventral accessory processes. As these are distinctive features of the Pacific and Gulf of Mexico specimens it seems reasonable to assume that they are identical with those of van Beneden.

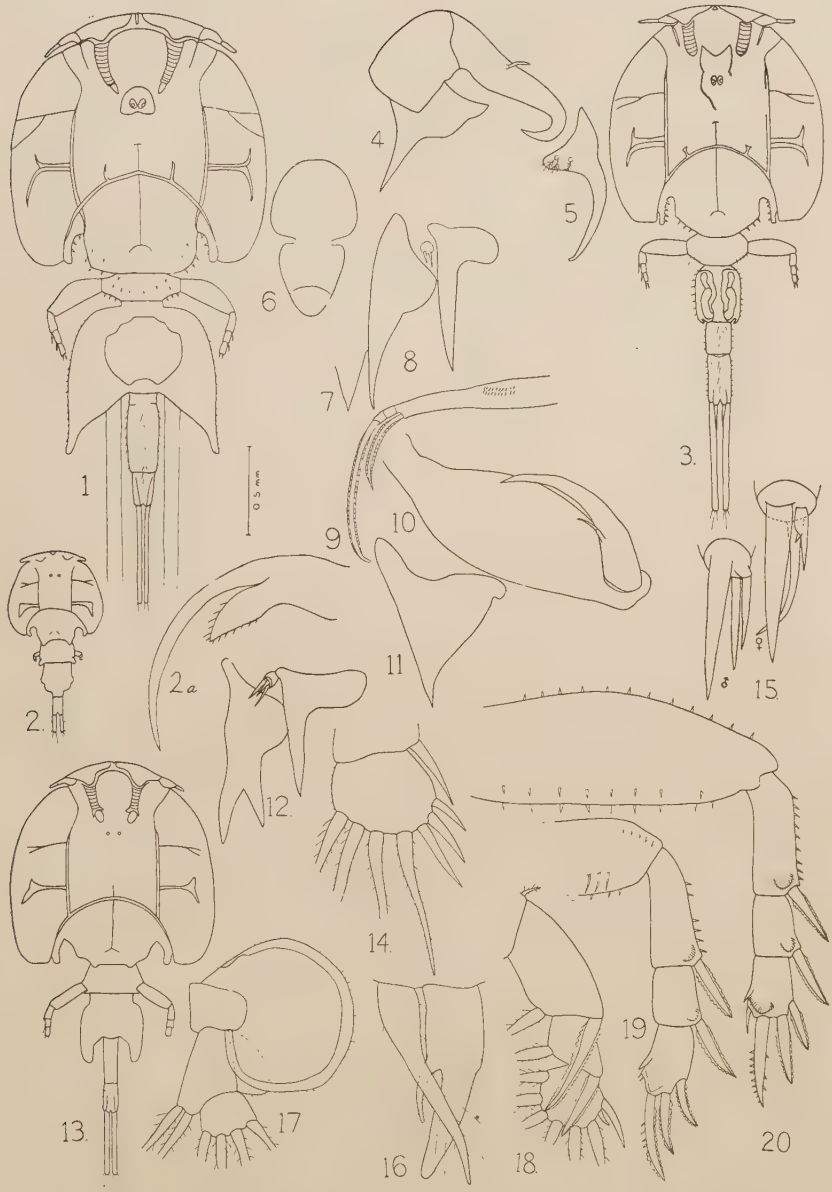
The form described by van Beneden as the male of *Pupulina flores* has been stated by C. B. Wilson (1935a, 1935b) to be an immature female of *Paralebion elongatus* C. B. Wilson.

PUPULINA MINOR, new species

PLATE 13

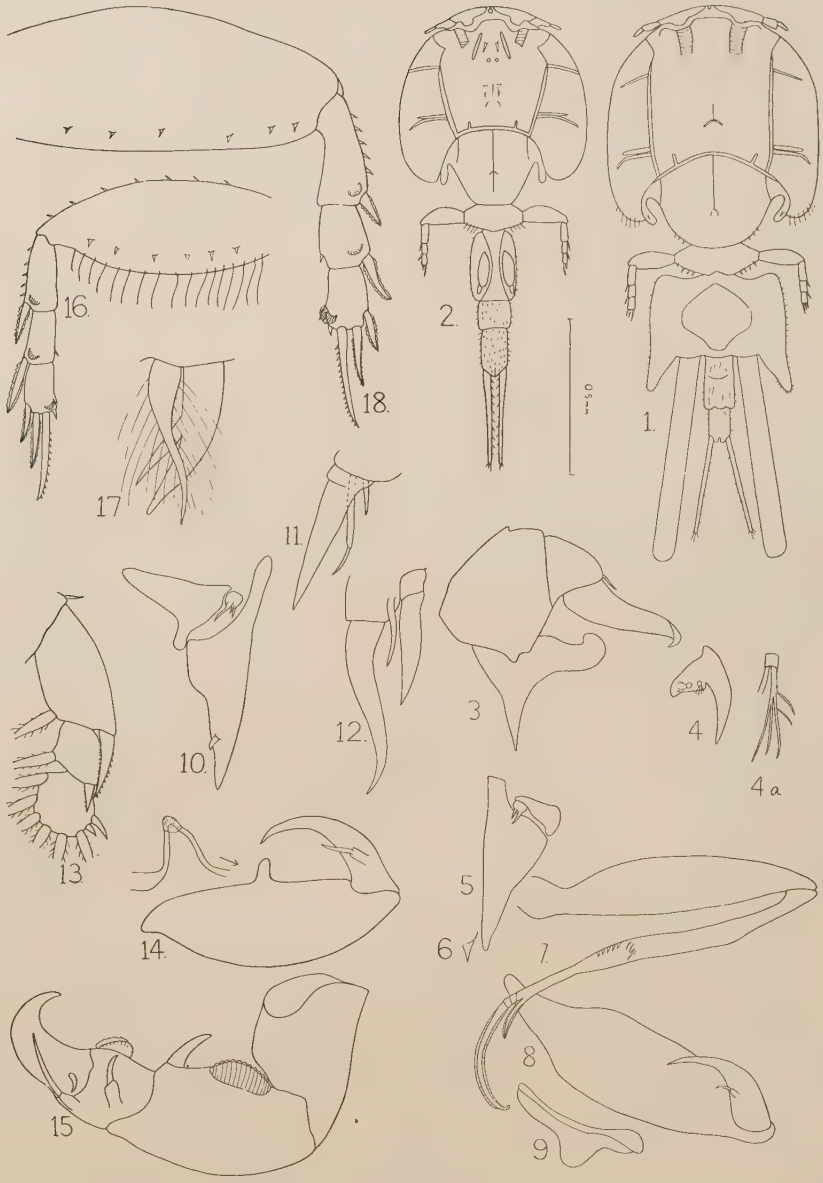
Pupulina flores, in part, BERE, 1936, p. 590, the "smaller" specimens.

Specimens examined.—Two females, one ovigerous; two males; collected by G. E. MacGinitie, from the giant ray *Mobula lucasana* Beebe



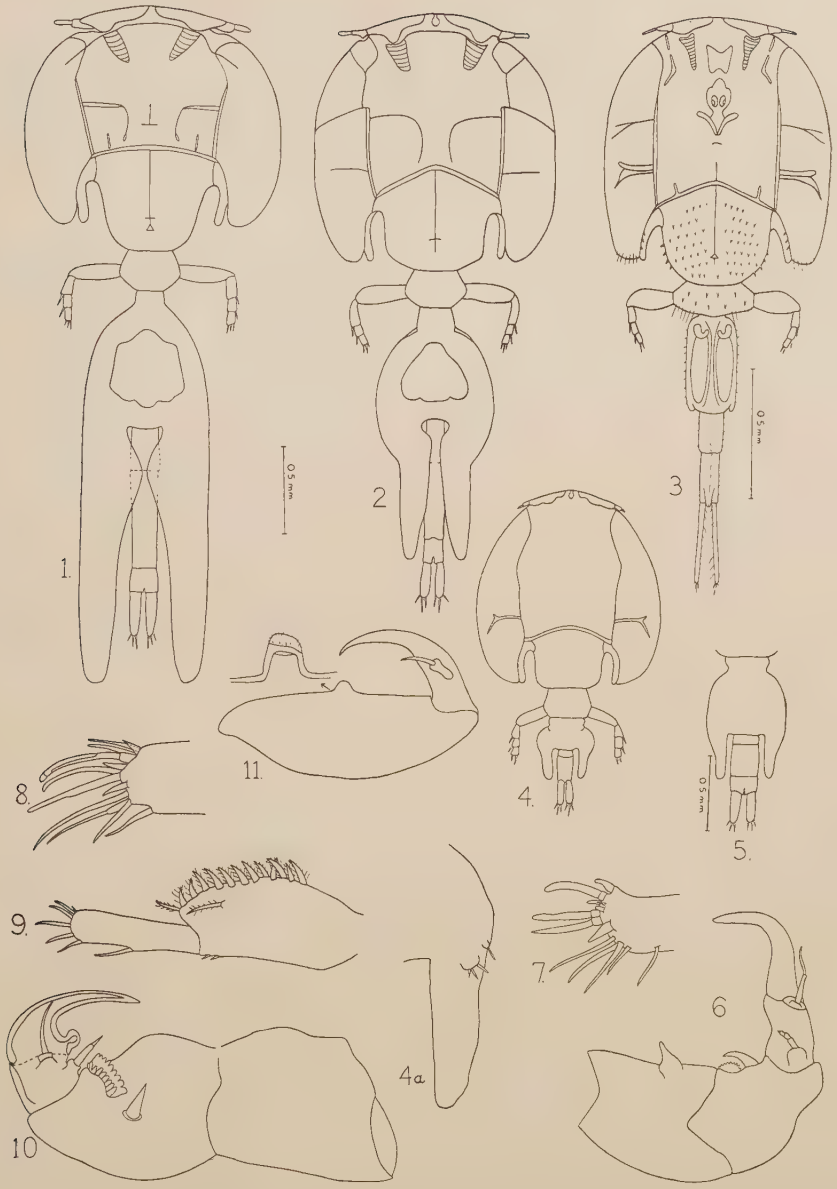
PUPULINA FLORES VAN BENEDEN

1, Female, dorsal view of adult. 2, Female, dorsal view of chalimus, stage *a*. 2, *a*, Claws of maxilla 2, stage *a*. 3, Male, dorsal view. 4–11, Female, cephalic appendages in situ: 4, Antenna 2; 5, lateral hook; 6, outline of mouth tube; 7, anterior ventral accessory process; 8, maxilla 1; 9, apex of maxilla 2; 10, maxilliped; 11, posterior ventral accessory process. 12, Male, maxilla 1. 13, Female, dorsal view of chalimus, stage *b*. 14, Female, leg 3, exopod segment 3. 15, Male and female, papillary setae of maxilla 1. 16, Female, leg 1, modified spine of exopod. 17, Female, leg 3, endopod. 18, Female, leg 2, exopod. 19, Male, leg 4. 20, Female, leg 4. (Scale applies to figures 1–3 and 13.)



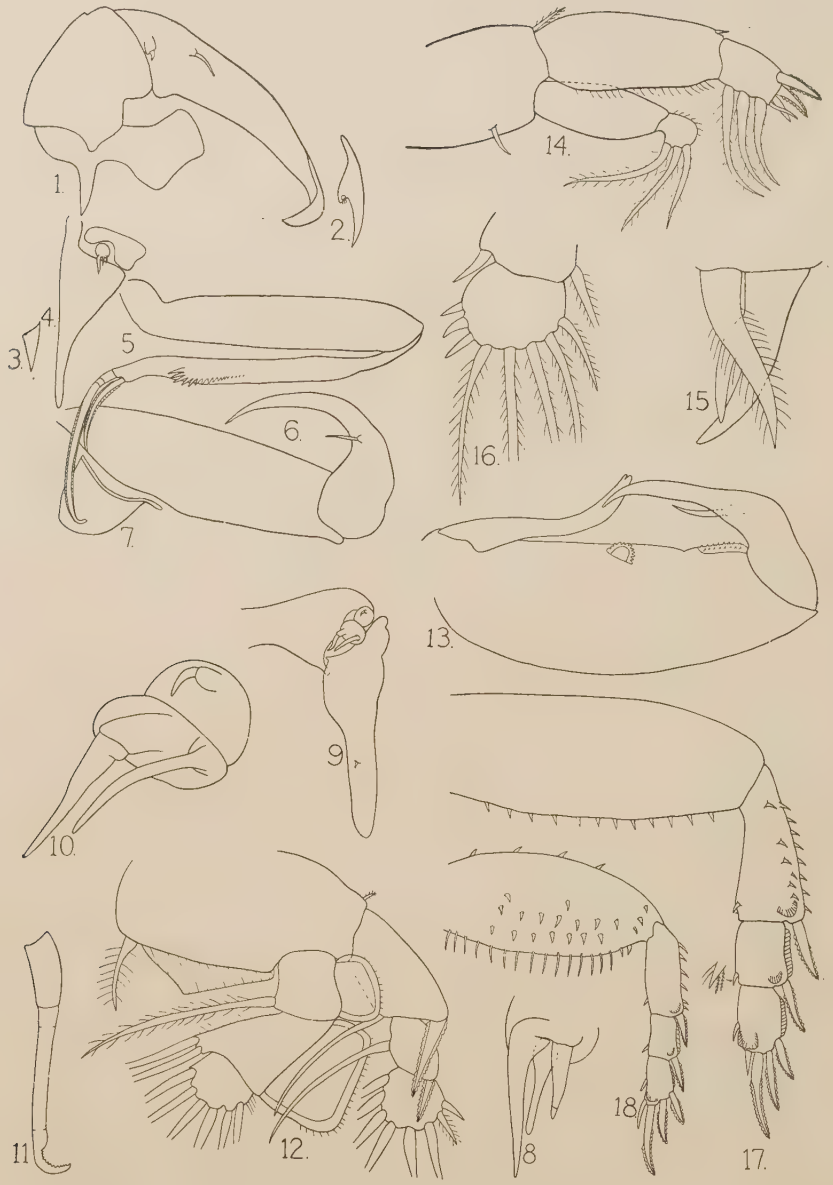
PUPULINA MINOR, NEW SPECIES

1, Female, dorsal view. 2, Male, dorsal view. 3–9, Female, cephalic appendages in situ: 3, Antenna 2; 4, lateral hook; 4, *a*, papillary seta of hook; 5, maxilla 1; 6, anterior ventral accessory process; 7, maxilla 2; 8, maxilliped; 9, posterior ventral accessory process. 10, Male, maxilla 1. 11, Female, papillary setae of maxilla 1. 12, Male, papillary setae of maxilla 1. 13, Female, leg 2, exopod. 14, Male, maxilliped, with detail of papilla. 15, Male, antenna 2, greatly enlarged. 16, Male, leg 4. 17, Female, leg 1, modified spine of exopod. 18, Female, leg 4. (Scale applies to figures 1 and 2.)



PUPULINA BREVICAUDA, NEW SPECIES, AND P. FLORES VAN BENEDEN

Pupulina brevicauda: 1, Female, dorsal view of adult; 2, young female, dorsal view; 3, male, dorsal view; 4, female, dorsal view of chalimus, stage *b;* 4, *a,* ventral view of genital segment, stage *b,* with legs 5 and 6; 5, female, stage *c,* posterior part of body, dorsal view; 6, male, antenna 2, greatly enlarged; 7, female, terminal portion of antenna 1. *P. flores:* 8, Female, enlarged terminal portion of antenna 1; 9, female, antenna 1; 10, male, antenna 2, greatly enlarged; 11, male, maxilliped, with detail of papilla. (Scale between figures 1 and 2 applies to figures 1, 2, and 4; scales at figures 3 and 5 apply to those figures only.)



PUPULINA BREVICAUDA, NEW SPECIES

1–7, Female, cephalic appendages in situ: 1, Antenna 2; 2, lateral hook; 3, anterior ventral accessory process; 4, maxilla 1; 5, maxilla 2; 6, maxilliped; 7, posterior ventral accessory process. 8, Female, papillary setae of maxilla 1. 9, Male, maxilla 1. 10, Male, papillary setae of maxilla 1. 11, Female, mandible. 12, Female, leg 2. 13, Male, maxilliped, greatly enlarged. 14, Female, leg 1. 15, Female, leg 1, modified spine of exopod. 16, Female, leg 3, exopod segment 3. 17, Female, leg 4. 18, Male, leg 4.

and TeeVan; off Santa Catalina Island, Calif.; October 3, 1946.

Three females, two ovigerous; three males; collected by Ruby Bere, "around the mouth of a devilfish (probably *Mobula hypostoma*)," Lemon Bay, Fla., Gulf of Mexico. Identified and reported as *Pupulina flores* by Bere (1936).

Types.—Holotype female, U.S.N.M. No. 85973; allotype male, U.S.N.M. No. 85972; Gulf of Mexico specimens.

Diagnosis.—Length of anterior and posterior parts of body approximately equal in both sexes. Processes of genital segment of female reaching to near the middle of the abdomen. Caudal rami linear and a little longer than abdomen in both sexes, attached laterally, divergent in female. Outer piece of first maxilla not produced distally in female, only slightly so in male; inner piece in male with small spine near distal outer margin. Male maxilliped with process of basal segment elongated. Posterior ventral accessory processes with small lobed membranous extension distally. Leg 4 with inside spine on segment 3, cuticular process on segment 4.

Description.—Female (pl. 13, fig. 1): Gulf of Mexico specimens: Total length, 6.8–7.0 mm.; average length and width of carapace, 3.2 mm. California specimens: Total length 5.9 mm.; length and width of carapace, 2.5 mm.

Anterior and posterior margins of carapace curved; sides slightly rounded. Median sinus a small rounded pit; posterior sinuses rather shallow. Distal edges of lateral area set thickly with long hairs, edge of thoracic area with a few spinules. Main lines of dorsal grooving well defined, that of central cephalic area not distinct in available specimens.

Free thoracic segment almost three times as wide as long; posterior margin set with very minute spinules. Genital segment two-thirds wider than long at middorsal line; sides tapering gradually, armed marginally with short spinules. Processes with rounded points, extending nearly to the middle of the abdomen; inside, the processes not arising on either side of the base of the abdomen as in *P. flores*, the posterior margin of the genital segment being extended beyond this point. Design on dorsal surface of genital segment with rounded peak at top, and single lobes at side and bottom; this pattern identical in the two lots of specimens. Ovisacs reaching slightly beyond end of caudal rami in all specimens.

Abdomen slender, indistinctly 3-segmented; a dorsal inflation of the anterior portion of the proximal part the only indication of its division into two joints; this basal portion almost twice the length of the anal segment; both set with marginal spinules, dorsal surface with long slender hairs. Caudal rami slender, a little longer than abdomen; attached to the anal segment laterally, and divergent from

one another; inner and outer margins set with very short, scattered spinules. End of rami bearing terminally a short, broad, spiniform seta and three longer, nonplumose setae, one lateral and one short ventral seta.

Second antenna (pl. 13, fig. 3) with spinous process of basal segment well developed; third segment more or less distinct; terminal claw comparatively weak and little curved, with a slender seta at its base. Prehensile lateral hook (pl. 13, fig. 4) short, with broadened base, not strongly curved; setae of papillae branched (pl. 13, fig. 4, *a*). Mouth tube as described for the genus, well developed and seeming large in proportion to the comparatively small size of the copepod.

First maxilla (pl. 13, fig. 5) having the inner piece well extended distally and the outer portion with a small posterior extension not reaching beyond the curved basal part of the inner piece; the longest of the three papillary setae (pl. 13, fig. 11) very broad and partially divided near its base, the other two very slender, the longer consisting of two unequal segments. The anterior ventral accessory process (pl. 13, fig. 6) located near the distal inside end of the inner piece of the first maxilla, a small spine terminating a membranous fold that runs backward about half the length of the maxilla (this membrane not shown in pl. 13, fig. 6).

Posterior claw of second maxilla (pl. 13, fig. 7) only one-third the length of the anterior. Claw of maxilliped (pl. 13, fig. 8) very short, with an accessory seta. Posterior ventral accessory process (pl. 13, fig. 9) consisting of a stout curved chitin rod and a membranous extension with a small distal lobe. Rod between the bases of legs 1 and 2 broadened, unarmed, curved backwardly.

Legs 1–3 of the same form as in other species of the genus; modified spine of leg 1 as illustrated in plate 13, figure 17. Exopod of leg 2 (pl. 13, fig. 13) with outer spine of first segment very stout, reaching only a little beyond the second segment; that of segment 2 reaching to about the middle of the third segment. First spine of third segment curved downward, reaching only a little beyond distal margin of the segment; second spine straight, about half the length of the first. Leg 3 similar to that of *P. flores*.

Leg 4 (pl. 13, fig. 18) with the basal segment broadened and armed with scattered spines; segment 2 having marginal outer spinelets and a thin ventral lamina distally. All the major spines with toothed margins. The terminal spines of segment 4 considerably elongated, the longest being about twice the length of the segment; the innermost spine attached laterally and unusually short. Segment 3 with a short lateral spine inside; the fourth segment with a curved cuticular process (or imperfectly separated spine), covered ventrally by the lamina which extends outward from the distal edge of the segment.

MALE: Gulf of Mexico specimens: Total length, 5.7–6.1 mm.; width of carapace, 2.2–2.5 mm.; length of carapace, 2.3–2.8 mm. California specimens: Total length, 4.8 mm.; width of carapace, 2.0 mm.; length of carapace, 2.1 mm.

Carapace suborbicular, longer than wide; posterior sinuses shallow; thoracic area somewhat elongated and narrowed behind the sinuses. Pattern of cephalic area not distinct in specimens available, except for two anterior ridges, between which are a pair of rather stout spines; another pair of spines located a short distance posterior to the eyes; these spines apparently easily broken off, as in no single specimen are they all intact.

Free segment about two and one-half times wider than long, with long dorsal hairs posteriorly. Distal corners of genital segment hardly produced. Abdomen about as long as genital segment, 2-segmented, set marginally and dorsally with fine spinules. Caudal rami one-fourth longer than abdomen, attached laterally as in female, but not divergent; not twisted and flattened laterally to such an extent as those of *P. flores*, but with similar long hairs inside. Caudal setae as in female.

Prehensile lateral hook hardly stouter than that of female, setae of papillae unbranched. Second antenna (pl. 13, fig. 15) comparatively stout; basal segment well differentiated from ventral surface, second segment armed with a large, ridged lamina and a stout spine; the third with a 2-layered lamina, a spine and a seta, both of which arise from large stalks; claw short but strongly curved.

First maxilla (pl. 13, fig. 10) with inner piece elongated distally as in female, but bearing at outer distal third a stout recurved spine; basal outer piece with distal outer lobe larger than in female and extended slightly beyond the curved basal part of the inner piece; papilla (pl. 13, fig. 12) with the three usual setae, the medial being very slender.

Maxilliped (pl. 13, fig. 14) with stout terminal claw, armed with a seta on a long stalk; basal segment having a prominent process similar to that of *P. flores*, but more elongated. Anterior ventral accessory process with smaller spine than in the female; posterior process like that of female.

Rod between legs 1 and 2 with posterior, upwardly directed lobes, apparently unarmed. Legs 1–3 like female; leg 4 (pl. 13, fig. 16) like female except that in addition to scattered spines, the basal segment is set dorsally with very long slender hairs.

Color.—MacGinitie (1947) has recorded the following notes on the color of the California specimens: "The smaller of the two new species of copepods had a wine-colored eyespot. The body and tail were transparent, with wine and blue lines and patches over the body. The

eggs were salmon colored." Bere (1936) referred to the "smaller females" (Gulf of Mexico specimens) which are here designated as belonging to this species, as having the carapace "creamy with much branched reddish purple pigment spots; genital segment and egg strings rose colored; eyes black."

Remarks.—The only noticeable differences between the Gulf of Mexico specimens and those from the Pacific are in the larger size of the former and in the thicker integument of the latter.

It is interesting to note that this species occurred in both collections with another species of the genus, in the Gulf of Mexico with *Pupulina flores* and in the Pacific with the other new species herein described.

The name *minor* refers to the notably small size of this species, compared with that of the other known species.

PUPULINA BREVICAUDA, new species

PLATE 14, FIGURES 1–7; PLATE 15

Specimens examined.—Eight females, 2 adult, nonovigerous, others in various development stages; 16 males, 2 attached to immature females; collected by G. E. MacGinitie, from around the mouth and anterior end of the giant ray *Mobula lucasana* Beebe and TeeVan; off Santa Catalina Island, Calif.; October 3, 1946; occurring with *Pupulina minor.*

Types.—Holotype female, U.S.N.M. No. 85977; allotype male, U.S.N.M. No. 85976.

Diagnosis.—Posterior part of body in female longer than the anterior; a little shorter in the male. Both abdomen and processes of the genital segment of female greatly elongated, the latter reaching a little beyond distal end of caudal rami. Caudal rami of female short and broad, only about one-fifth of the total length of the abdomen; linear in male, almost as long as abdomen. Basal portion of outer piece of first maxilla not produced distally in female, hardly so in male; inner piece of male with minute spine near distal outer margin. Male maxilliped with large curved, clawlike process at its base. Posterior ventral accessory processes large membranous lobes in female, not so well developed in male. Leg 4 with inside spines on segments 2–4.

Description.—FEMALE (pl. 14, fig. 1): Measurements of holotype: Total length about 14.8 mm.; length of cephalothorax, 6 mm.; posterior part of body, 8.8 mm.; length of carapace, 5.2 mm.; width of carapace, 6.0 mm. Total length of paratype, 14.5 mm.; width of carapace, 6.0 mm.

Carapace a little wider than long; anterior and posterior margins only slightly curved, sides well rounded. Anterior sinus hardly distinguishable; posterior sinuses deep. Dorsal pattern of carapace

uniquely distinguished by the pair of transverse lines of the mid-cephalic area, these carried backward by curved lines ending in small loops; midanterior portion with a design similar to that of the male (pl. 14, fig. 3), but not entirely clear in available specimens. Ventral supporting ribs of the lateral area not visible dorsally in holotype, partially so in paratype.

Free segment about one-fourth wider than long, posterior edge straight. Genital segment with a narrow neck, anterior portion (exclusive of neck and processes) a little longer than wide; sides rounding out from neck and extending straight backward in long, narrow processes, almost twice as long as the main portion of the segment and reaching a little beyond the tip of the caudal rami; in the paratype female, the processes slightly shorter than the rami. Processes well rounded apically, partially covering the abdomen in the proximal inner area; sides curved under and more or less grooved ventrally; the surface integument relatively thin and lacking hairs or spinules. Top of dorsal pattern of segment with well-rounded lobe in middle, slanting sides, and five posterior lobes, of which the central is the longest.

Abdomen slender, elongate, with three distinct segments; the middle the longest, the anal the shortest; the first two segments together six times the length of the anal; margin set with very fine short hairs. Caudal rami about one-fourth as broad as long; differing from those of other females of the genus in being somewhat flattened, very short and broad; equaling only a little more than a fourth of the total length of the abdominal segments; slightly less than twice the length of the anal segment; tipped with three very short setae.

First antenna with fewer plumose setae on the basal segment than in *P. flores*, armed terminally as in plate 14, figure 7. Second antenna (pl. 15, fig. 1) with a stout basal spinous process, terminal claw exceptionally long, armed proximally with a stalked spine and a long seta. Lateral hook (pl. 15, fig. 2) very short, hardly curved, setae of basal papillae little developed. Mouth tube as for the genus; claw of mandible (pl. 15, fig. 11) with 12 teeth. Anterior ventral accessory processes short, narrow, membranous spines (pl. 15, fig. 3), larger than those of *minor*, smaller than those of *flores*.

First maxilla (pl. 15, fig. 4) with posterior lobe of outer portion not extended beyond base of inner piece; setae of papilla subequal (pl. 15, fig. 8), the shortest divided near the tip, the middle one with the basal part rounded and swollen; inner piece with distal extension very slender. Posterior claw of second maxilla (pl. 15, fig. 5) about half the length of the anterior. Maxilliped (pl. 15, fig. 6) with moderately strong claw, set with a slender seta. Posterior ventral accessory process (pl. 15, fig. 7) a somewhat large, membranous, rounded flap attached to a narrow chitinous bar.

Rod between legs 1 and 2 narrow, unarmed. Legs 1–3 of the usual form for the genus. Leg 1 (pl. 15, fig. 14) with endopod reaching to distal end of first exopod segment; modified spine and seta of exopod 2 as in plate 15, figure 15.

Leg 2 (pl. 15, fig. 12) with the outer spine of first exopod segment reaching to the proximal third of segment 3; that of segment 2 reaching a little beyond the middle of the third segment. First spine of third segment curved downward, shorter than the second, which is setiform and sparsely plumose. Laminae of endopod with somewhat straight outer edges.

Exopod of leg 3 with outer spine of segment 2 reaching to about middle of third segment; outer spines of segment 3 (pl. 15, fig. 16) all very short, subequal; differing from *flores* and *minor* in the presence of a fifth plumose seta inside, this seta shorter and more slender than the others. Endopod like that of *flores* except that the lower part of the lamellar expansion of segment 2 is much larger, extending distally almost to the end of the third segment.

Leg 4 (pl. 15, fig. 17) with the basal segment comparatively narrow, set with short spines posteriorly. Segments 2–4 bearing short spinules inside, that of segment 4 the longest, placed just below the middle of the segment; this latter spinule apparently homologous to the imperfectly separated cuticular process of the other two species. Second segment with an irregular double row of outer marginal spinelets; segments 3 and 4 with narrow marginal laminae. Major spines of all segments stout and comparatively short, the longest of the terminal spines being only a little longer than its segment. The distal portion of segment 4 almost squarely truncated, with the inner spine thus placed in a terminal position; this spine straight and stout, a little less than one-third the length of the longest terminal spine.

Male (pl. 14, fig. 3): Average total length, 8.7 mm.; length of cephalothorax, 4.7 mm.; width of carapace, 3.7 mm. Carapace longer than wide, anterior and posterior margins rounded, sides nearly straight. Cephalic area with well-defined dorsal patterns, transverse lines more or less distinct as in female. Spinules set thickly on dorsal surface of thoracic area, thinly scattered over the rest of the carapace. Free thoracic segment almost three times wider than long, set dorsally with spinelets and posteriorly with long hairs.

Genital segment and abdomen approximately equal in length. Genital segment about twice as long as broad, with small distal processes; surface covered dorsally and ventrally with minute spines. Anal segment a little longer than the basal segment of the abdomen; caudal rami slightly shorter than the abdomen, linear as in other males of the genus. Abdomen with center line of long coarse hairs; caudal rami with similar coarse hairs on inside margins.

Lateral prehensile hook stouter than that of female, about as long as terminal claw of second antenna; the setae of basal papillae long, slender, and unbranched. Antenna 2 (pl. 14, fig. 6) with a cuticular process on basal segment; a stout, curved spine and small laminate process on segment 2; a 4-jointed, broadly stalked seta on segment 3; terminal claw stout and strongly curved, though relatively short, the seta at its base long and 2-jointed. First maxilla (pl. 15, fig. 9) having the basal outside portion of the outer piece widened transversely with a slight distal extension inside; papilla (pl. 15, fig. 10) of two parts, the upper with a very short spine, the lower with two subequal setae, the outer seta very broad and set on a stout basal stalk; inner piece slender throughout, having at its distal outer third a very small curved spine. Maxilliped (pl. 15, fig. 13) with a small lamina at the middle of the basal segment, and an unusual clawlike process with a divided tip, attached basally.

Leg 4 (pl. 15, fig. 18) with broad basal segment set with stout spinules and long coarse hairs. Segments 2–4 with inside spines and outer marginal laminae as in female; apex of segment 4 not so squarely truncated, terminal inside spine slender and curved, comparatively longer than that of the female.

Development Stages: Three development stages of the female are represented in the collection. None is so immature as the earliest stage (*a*) described for *Pupulina flores*. The youngest, however, corresponds very closely to stage *b* of *P. flores*, and so is likewise designated as stage *b*. Stage *c* is probably the one immediately following this in natural development. Other forms designated as *young females* are considered to represent early growth stages of the adult copepod.

No filament was ascertained to have been present in any of the specimens, but there is a small ventral structure that is interpreted as being a filament gland.

Stage *b* (pl. 14, fig. 4): Two specimens, to one of which a male is attached to the dorsal neck of the genital segment, clinging by means of the claws of its second antennae.

Total length, 7.8 mm.; cephalothorax, 5.5 mm.; posterior part of body, including caudal rami, 2.3 mm. All the first three thoracic segments incorporated in the carapace, which is a little longer than wide; frontal plates distinct.

Processes of genital segment reaching almost to the end of abdomen. Abdomen 2-segmented, the anal segment not being differentiated. Caudal rami having the short, broad form characteristic of the species; in this stage they are almost as long as the abdomen.

All of the appendages completely segmented, but not so strongly developed as those of the adults. The inner piece of the first maxilla

not reaching beyond the tip of the anterior ventral process; maxillae and maxilliped crowded together as in adult. Claws of second maxilla short and weak, as noted for immature forms of *P. flores*. Anterior ventral accessory processes very small spines; the membranous flap of the posterior process hardly separated from the tissue of the ventral face, but the outline discernible.

Legs 1–3 completely segmented, with the laminae also well developed. Leg 4 with all the segments indicated, but very short, the whole structure appearing thin; all the spines, including the inside marginal ones, present but very short and weak. Rudiment of leg 5, a lobe hardly differentiated from the surface and bearing three short setae, present ventrally on the proximal surface of the genital process near the outer edge (pl. 14, fig. 4, *a*); leg 6, represented by a single seta attached to a minute lobe, located anterior to the fifth pair, the seta projecting beyond the margin of the genital segment.

This form is closely similar to that described as stage *b* for *P. flores*, and undoubtedly represents the same period in development. That it can properly be interpreted as a chalimus stage, though a very late one, can be seen not only from the shape and size of the genital segment and abdomen, but by the incompleteness of segmentation of the latter. The appendages, though completely segmented, are thin and weak, and the claws of the second maxillae have not assumed the adult form. In addition, legs 5 and 6 are at the height of their development, requiring passage through another stage before disappearing.

Stage *c* (pl. 14, fig. 5): One specimen, male attached. Total length, 11.0 mm.; cephalothorax, 6.5 mm.; posterior part of body, including caudal rami, 4.5 mm.; width of carapace, 6.5 mm.

Genital processes only slightly longer than in stage *b*, but abdomen considerably longer, showing division into three segments.

All appendages more strongly developed than in preceding stage. Distal extension of inner piece of first maxilla reaching well beyond the tip of the anterior ventral process. Claws of maxilla 2 as in the adult. Spines of leg 4 considerably longer and thicker. Ventral accessory processes as in stage *b*. Legs 5 and 6 still present, but the setae much shorter than in preceding stage.

Whether this stage is to be interpreted as a chalimus or a growth form of the adult is not clear. Although the appendages are more strongly developed than in Stage *b*, they are still thin and weak compared to the young or adult female. In addition to the comparatively short abdomen and the small genital segment, there are still present the rudiments of legs 5 and 6.

Young female (pl. 14, fig. 2): Three females, measuring between 13.1 and 13.5 mm., show differences in the length of the processes of the genital segment: Slightly shorter than the anal segment (as fig-

ured); slightly shorter than the caudal rami; as long as the caudal rami. These must represent different growth stages of the mature copepod; they differ from the adult only in their lesser length, in having the anterior and posterior parts of the body approximately equal in length, the carapace not so wide, and in very slight differences in the dorsal pattern of the genital segment.

Color.—MacGinitie (1947) has recorded this species as being transparent and without colored markings; eyespot black.

Remarks.—MacGinitie has further noted that this species was parasitized by a trematode, the egg cases being attached mainly to the abdominal area. It may or may not be of significance that the right caudal ramus of the holotype female, which is a little shorter than the left, and the left genital process of the paratype female, which is a little shorter than the right, are each much more heavily infested by the trematode egg cases than any other area.

The name *brevicauda* refers to the very shortened caudal rami, particularly conspicuous in the female, though it is to be noted that those of the male are comparatively much shorter than those of other species.

LITERATURE CITED

BASSETT-SMITH, P. W.

1899. A systematic description of parasitic Copepoda found on fishes, with an enumeration of the known species. Proc. Zool. Soc. London, 1899, pp. 438–507, pl. 26.

BENEDEN, P. J. VAN.

1892. Quelques nouveaux Caligidés de la côte d'Afrique et de l'archipel des Açores. Bull. Acad. Roy. Sci. Belgique, ser. 3, vol. 24, pp. 241–262, 4 pls.

BERE, RUBY.

1936. Parasitic copepods from Gulf of Mexico fish. Amer. Midl. Nat., vol. 17, pp. 577–625, 12 pls.

MACGINITIE, G. E.

1947. Notes on the devilfish, *Mobula lucasana*, and its parasites. Copeia, 1947, No. 4, pp. 276–278, 2 figs.

WILSON, CHARLES BRANCH.

1905. North American parasitic copepods belonging to the family Caligidae. Part I.—The Caliginae. Proc. U. S. Nat. Mus., vol. 28, pp. 479–672, pls. 5–29.

1935a. A parasitic copepod, *Pupulina flores*, redescribed after forty years. Parasitology, vol. 27, pp. 593–597, 13 figs.

1935b. Parasitic copepods from the Dry Tortugas. Papers Tortugas Lab., vol. 29, Carnegie Inst. Washington Publ. 452, pp. 327–347, 6 pls.

U. S. GOVERNMENT PRINTING OFFICE: 1952